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TROPICAL YAMS AND THEIR POTENTIAL

Part 2. *Dioscorea bulbifera*

Agriculture Handbook No. 466

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The feeding of future generations requires a knowledge of the individual crop plants of the world and their potentials. Crops can be recommended for use in particular regions only on the basis of potential yield, the costs of production, the food and feed value of the crop, and the way the crop can be processed or otherwise used. For most of the major food crops of the world, a body of information is already available. However, tropical roots and tubers, which are widely used as staple foods, have been largely neglected. Only in recent years has an awareness been growing of the potential of these crops to supply large amounts of food in relatively small amounts of space.

Yams are the second most important tropical root, or tuber, crop. The annual production, perhaps 25 million tons, places them second in importance to cassava. But yams are better food than cassava, and while they are usually thought to be more difficult to grow, under some conditions yams outproduce cassava. Yams fill an important role in the diet of many areas of the Tropics—a role that can increase in importance. That role and its potential are not, however, well understood.

The yam is not a single species. Perhaps 60 species have edible tubers; of these about 10 species can be considered crop plants. The literature concerning these species is widespread but fragmentary. This is the second in a series of Agriculture Handbooks dealing with the major species of yams. It is part of a research effort cosponsored by the Agricultural Research Service of the U. S. Department of Agriculture and the U. S. Agency for International Development to introduce, evaluate, and distribute better yam varieties.

Also in "Tropical Yams and Their Potential" series—

Part 1. *Dioscorea esculenta*. USDA Agriculture Handbook No. 457.

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TROPICAL YAMS AND THEIR POTENTIAL

Part 2. *Dioscorea bulbifera*

By FRANKLIN W. MARTIN, *plant geneticist, Federal Experiment Station, Southern Region, Agricultural Research Service, U. S. Department of Agriculture, Mayaguez, P.R.*

INTRODUCTION

One of the most common and widespread yams of the Tropics is *Dioscorea bulbifera* L., the air-potato yam, so called because it is grown chiefly for its edible aerial tubers. Known in both Asia and Africa for centuries, it has been widely distributed through the activities of man and has gone wild in many tropical regions. The species is best known in India, where there are superior edible varieties, but it is also common in West Africa. *D. bulbifera* probably is only a poor fourth or fifth in worldwide production of yams, for it is surpassed by *D. alata* L., the Asian greater yam; *D. rotundata* Poir. and possibly *D. cayenensis* Lam., the West African yams; and *D. esculenta* (Lour.) Burk., the Asian lesser yam. Although not one of the best yams, some varieties produce large numbers of aerial tubers over long periods of time, making them especially suited to the home garden. In addition, some also produce underground tubers. The better varieties are not well distributed, but merit introduction and trial.

History and Origin

D. bulbifera is the only edible yam species native to both Asia and Africa. The African varieties are so distinct from the Asian that their distribution must have taken place in prehistoric times. Perhaps the species had two centers of diversity, one in Indochina, Malaya, or Indonesia, and the other in Africa. Although Coursey (*4*)[1] speaks only of the former center, two closely related species in East Africa, *D. asteriscus* Burk. and *D. paleata* Burk., suggest an African center of diversity also. Burkill (*1*) agrees with this hypothesis and suggests that the wide diversity of African varieties is due to the hand of man. Certainly the range of variation in West Africa is sufficient to indicate independent evolution of Asian and African forms. Furthermore, a major difference of shape is usually sufficient to distinguish Asian from African types. Whereas the former are more or less spherical, the latter are angular.

Geographic Distribution

Probably *D. bulbifera* can be found in every hot, humid, tropical region. Burkill (*1*) speaks of *D. bulbifera* as having extended to the most remote islands of the Pacific. Wild forms, usually bitter

[1] Italic numbers in parentheses refer to items in "Literature Cited," p. 19.

and often poisonous, are the most common. The more ennobled varieties usually do not survive in the wild for long periods.

D. bulbifera is not native to the Western Hemisphere. Nevertheless, it is so widespread that it is noted in most floras of the tropical countries of Central and South America. Because it is common, it has frequently been given colorful names such as mata gallina (kills hens). The more desirable forms of *D. bulbifera* are not widely distributed in the Western Hemisphere, and the species is not an important food anywhere within this region.

BOTANY

Classification

D. bulbifera L., because of its wide distribution, has many synonyms. The African forms have been distinguished as *D. latifolia* Benth., a name not regarded with favor now. Other synonyms include *D. anthropophagorum* A. Chev., *D. hoffa* Cordemog, *D. hofika* Jumelle & Perrier de la Bathie, *D. longepetiolata* Baudon, *D. oppositifolia* Campbell, *D. perrieri* R. Knuth, *D. sylvestris* de Wild., *D. violacea* Baudon, and *Helmia bulbifera* Kunth. The name *D. sativa* Thumb. is also sometimes seen in the literature, specifically with respect to the edible Asian varieties. This name has also been applied to other species, but it is botanically invalid. Among the common names are potato yam [used also for *D. esculenta* (Lour.) Burk.], airpotato yam, air potato, aerial yam, bulbil-bearing yam, and, in Spanish, ñame de gunda (bulbil-bearing yam).

D. bulbifera belongs to the section Opsophyton, an Old World section, with two other African species, *D. asteriscus* Burk. and *D. paleata* Burk., which are neither edible nor commercially valuable. In common with other yams, the airpotato yam belongs to the family Dioscoreaceae, of which *Dioscorea* is the principal genus. The family is usually classified among the monocotyledons, although some evidence of a second cotyledon has been found (*7*). The family is characterized by rhizomes, usually reduced to a nodeless structure. The male and female flowers, usually on separate plants, are small and often inconspicuous. The inferior ovary becomes quite prominent after fertilization. The floral pattern is based on sets of three.

Morphology

D. bulbifera is a glabrous vine that climbs by twining to heights of 12 meters or more (fig. 1). The stems range from thin (1-millimeter diameter) to thick (8-millimeter diameter) and twist to the left in twining. The leaves, often quite large, are alternate and usually orbicular, but with well-developed acuminate tails. They are cordate at the base. Details of the sinus between the lobes, of the tail, and of the degree of rugosity,

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FIGURE 1.—Mature *D. bulbifera* vines climbing bamboo poles for support.

folding, cupping, and reflexing of the leaf are varietal traits making identification possible (fig. 2). The leaves are usually glabrous, but in some varieties they are covered with a bluish bloom. Another trait useful for identification is the resistance of the leaf to leafspot disease, common in all yam-growing regions. The petiole, which is enlarged at the base, has earlike projections that often encircle the stem (fig. 3).

Only small seedlings have true roots, and these are short-lived. The principal adventitious roots arise from the crown, the region of the stem immediately above the tuber. Finer roots arise from the surface of the tuber itself in some, but not all, varieties.

The small flowers are frequently seen during summer. They are sessile and appressed to the peduncle in long racemes produced in the axils of the leaves (fig. 4). The male and female flowers superficially appear alike, but the female is easily recognized from its inferior ovary. The perianth ranges from green to white to slightly pink. The flowers produce a pleasant odor, which attracts bees and other insects.

The seed capsules are trilocular, 2 to 5 centimeters long, and rise vertically from the racemes (fig. 5). At maturity they dry and open

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FIGURE 2.—Typical leaves of five *D. bulbifera* varieties. Cultivated varieties are shown above, wild varieties below. (Two-fifths actual size.)

longitudinally, beginning at the distal tip. The seeds are eventually dislodged by the wind and may be carried some distance from the plant. The seed is surrounded by a membranous falcate wing, which is hooked at its attachment to the placenta. The flattened seed is at one end of the wing. There are 70 to 110 seeds per gram. Fresh seeds germinate readily in soil or on wet filter paper in 2 to 3 weeks. Seedlings grow to mature size and flower in 1 year (unusual among yams).

In common with many yam spe-

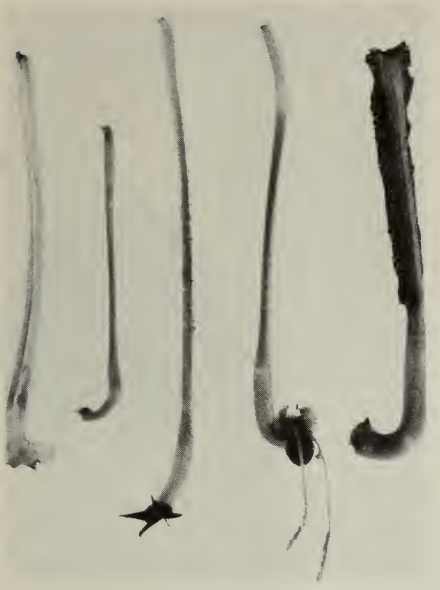

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FIGURE 3.—Petioles of five yam species. Left to right: *D. alata*, *D. rotundata*, *D. esculenta*, *D. bulbifera*, and *D. trifida*. Note the earlike projections, small aerial tubers, and flowering spikes of *D. bulbifera*. (One-half actual size.)

cies, *D. bulbifera* produces both underground and aerial tubers (fig. 6). The aerial tubers, or bulbils, such as those of *D. alata*, are often eaten, even though the underground tuber is the principal food part. Apparently man early selected the aerial tuber of *D. bulbifera* as the chief edible part, since some Asian and African varieties have evolved without significant underground tubers.

Aerial tubers begin to develop in the axil between leaf and stem (fig. 7) about the time that the leaf itself begins to unfold, and they grow rapidly. They are not produced until the plant reaches suitable maturity, but once production begins, it continues until the end of the season. Aerial tubers eventually fall from the vine. The time of fall depends on the variety. In some varieties tubers of all sizes fall, but in the better varieties, the tubers reach a suitable size and maturity before falling.

The aerial tubers of Asian varieties, which occasionally weigh a kilogram, are usually spherical to ellipsoid, but occasionally may be slightly flattened. The surface is characterized by many lenticels, which may be prominent or subdued. Otherwise, the surface is relatively smooth, with no adventitious roots. The exterior of improved varieties is usually a light tan or gray, but when anthocyanins are present, it may be very dark.

The aerial tubers of the African races are sharply angled and thus very different in appearance from the tubers of the Asian races. They are often characterized by depressions where preformed buds have developed. Color varies from gray or tan to dark brown. The dark tubers are often said to be poisonous, but in fact no correlation exists between color and alkaloid content.

The underground tuber, produced at an early stage in the seedling, arises from a swelling of the young stem and enlarges rapidly as a storage organ. It is quite distinct in external morphology from the root. Neither the true nor

PN—3674

FIGURE 4.—Male (*right*) and female (*center*) flowers of *D. bulbifera*, and an old inflorescence with two young seed capsules (*left*). (One-third actual size.)

adventitious roots ever give rise to tubers; rather, all tubers, aerial and underground, arise from stem tissues.

The characteristics of underground tubers vary from variety to variety also. No true tuber forms in some varieties, but roots and stems originate from a fibrous tuber remnant (fig. 8). From this extreme all degrees of development, from small to very large tubers, can be found in distinct varieties. The underground tuber resembles the aerial tuber to some extent. The Asian races produce spherical or ellipsoidal underground tubers (fig. 9), whereas those of the African races are very much more branched and irregular. Although the tubers of some varieties are covered with fibrous roots, others are completely smooth.

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FIGURE 5.—Mature capsules and seeds of *D. bulbifera.* (Actual size.)

The flesh (parenchymatous tissue) of the aerial and underground tubers is crisp, fine grained, and almost free of fibers. Color varies considerably among varieties. Many varieties contain anthocyanins, which in small quantities and combined with yellow pig-

ments produce pinkish or grayish flesh. In some cases the flesh has purple blotches. The flesh of most varieties is yellow owing to the presence of carotenoids. The flesh of the aerial tubers is usually the same color as that of the underground tubers, but the area just below the cork is colored bright green by chlorophyll. A small amount of chlorophyll is also found in the fleshy parenchyma.

When a tuber is cut, mucilaginous gums, or glycoproteins, exude from the cut surface. The surface

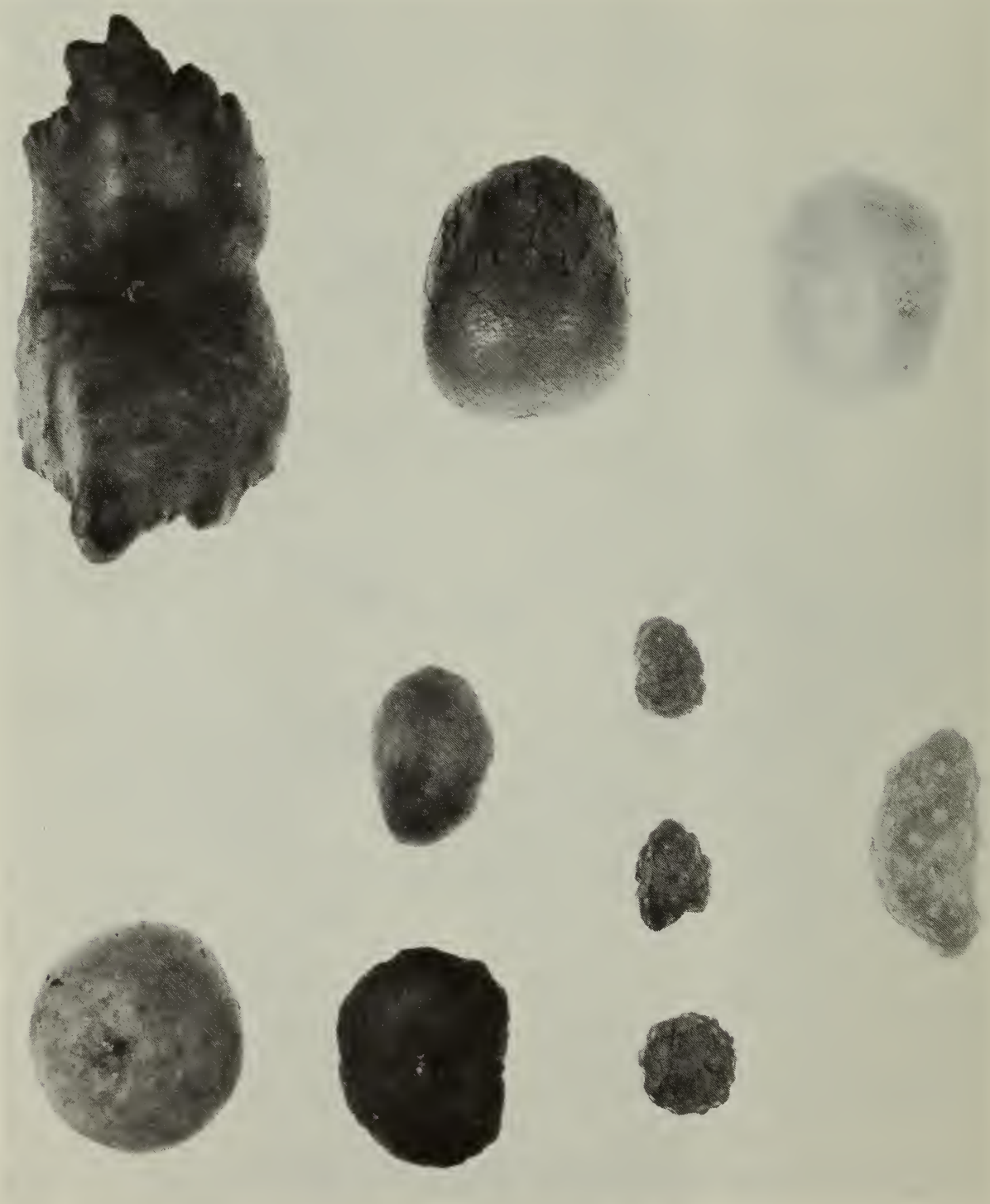

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FIGURE 6.—Aerial tubers of several African and Asian (three bulbils in lower left corner) varieties of *D. bulbifera*. (Two-fifths actual size.)

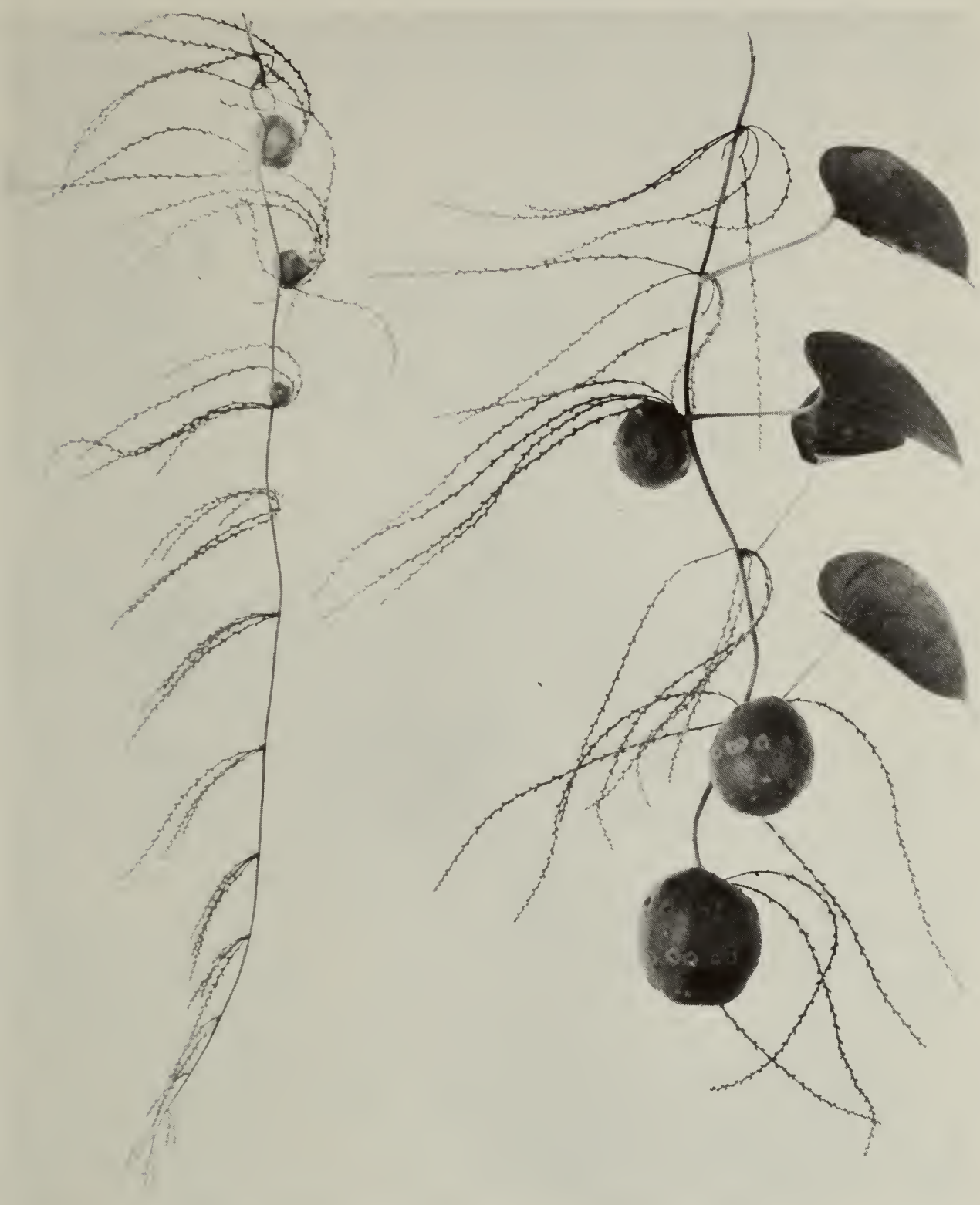

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FIGURE 7.—Aerial tubers and flowering spikes of *D. bulbifera* developing in leaf axils and terminal inflorescence. (Two-fifths actual size.)

oxidizes and turns brown within a short time after being cut. In this species of yam cuts and wounds heal naturally. After initial drying of the uppermost layers, the intact layers of cells below are impregnated with suberin, which effectively seals the wound and prevents further moisture loss and infection.

Cytology

Numerous chromosome counts have been made of *D. bulbifera*. In Asian varieties the chromosome numbers are multiples of 20, beginning with 40 (40, 60, 80, and 100). These numbers can be interpreted as polyploid numbers

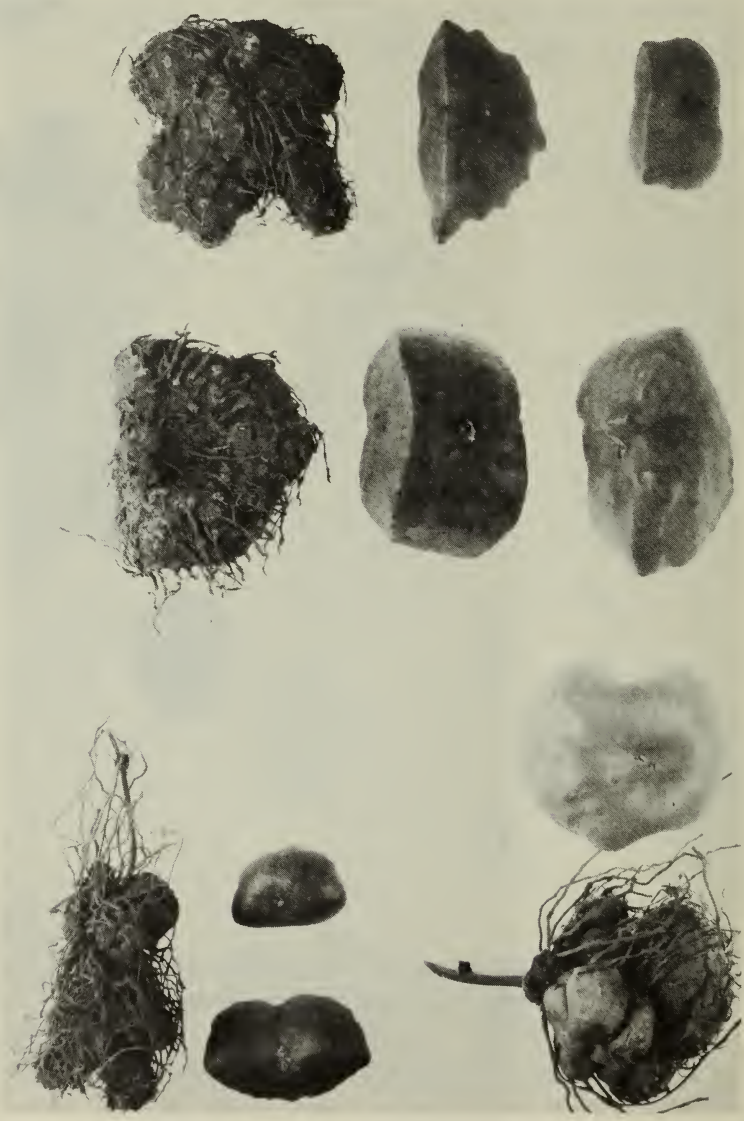

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FIGURE 8.—The fibrous underground tubers of some African varieties of *D. bulbifera* alongside the smooth aerial tubers of the same variety. (Two-fifths actual size.)

PN—3679

FIGURE 9.—Large underground tuber of *D. bulbifera* 'Sativa', an Asian variety. (Two-fifths actual size.)

based on a set of 10 (*8*). In West African varieties the chromosome numbers are 36, 40, 54, and 60, which are based on multiples of either 9 or 10. Evidently in the very early evolution of the species, a chromosome was lost in the progenitor of the 36- and 54-chromosome varieties. When large numbers of chromosomes occur, some multivalent figures are normally seen. Poor chromosome distribution and resulting genetic imbalance probably account for the sterility of some varieties.

Because many varieties flower freely, it should be possible to breed new varieties systematically, although there are no records of its having been done. Where male and female flowers of different plants are not too far apart, pollination occurs readily, and capsules with up to six seeds are produced. On the other hand, the failure of some combinations suggests that male or female sterility may occur.

Selection must have been practiced by early man. The many varieties in both Africa and Asia suggest that breeding, probably by selection for forms with large

aerial tubers, has been quite successful. Natural crossing among selected large-tubered males and females could lead to an increase in variation with respect to tuber size and to a gradual evolution of varieties with larger aerial tubers.

Hill selection of large-tubered, vigorous plants should be useful in maintaining healthy, productive stock, but must be continued each generation to be effective.

VARIETIES

Two important studies have been made of *D. bulbifera* varieties. The African varieties have been treated in depth by Chevalier (*2*), and the Asian species, by Prain and Burkill (*10, 11*). Whereas the latter study is conservative, in the former the African varieties are considered to be of a separate species (*D. latifolia* Benth.), and in fact are divided into several botanical varieties, as follows: *senegambica, sylvestris, anthropophagorum, contralatrones, longipetiolata,* and *violacea*. The differences among these varieties are real enough, but undoubtedly some have been given too much taxonomic weight. For example, varietas *contralatrones* differs from varietas *anthropophagorum* chiefly on the basis of the presence of poisons in one and not the other. The anthocyanin coloration in varietas *violacea* is probably not sufficient to distinguish it as a separate botanical variety.

Prain and Burkill (*11*) found great diversity in the Asian varieties of the species, especially with respect to the size and characteristics of the aerial tuber. This is always spherical to elongate, sometimes rather irregular in shape or lumpy, but never more than slightly flattened. The surface of the tuber may be very smooth or be roughened by the prominence of the lenticels. Four botanical varieties have been distinguished. The wild plant, with abundant, small aerial tubers and cordate leaves is varietas *bulbifera*. Another form with longer leaves has been named *heterophylla*. The cultivated forms have been distinguished as varietas *sativa*, with large, gray, smooth bulbils, and varietas *suavior*, with smaller, dark gray-brown bulbils having prominent lenticels.

Varieties can be considered from other standpoints, of course. Thus, they can be classified by their horticultural value. In this respect, the cultivated varieties of India and Southeast Asia are far superior in flavor and yield to any of the African varieties. A list of the principal varieties tested by the author is found in table 1.

The following characteristics are most useful in distinguishing varieties: size and shape of aerial tuber, size and shape of underground tuber, pattern and prominence of lenticels on aerial tuber, size and shape of leaves, diameter of mature stem, minor characteristics of leaf, color of flesh, and bitterness of cooked flesh.

The characteristics desired in a good variety include large, abun-

TABLE 1.—*Yields of* D. bulbifera *varieties from various regions*

Accession No.[1]	Source	Varietal name or characteristic	Yield (metric tons per hectare)		
			Aerial tubers	Underground tubers	Total
14861	Puerto Rico	cv. 'Sharp Angled'	4.90	0.00	4.90
15216	do	cv. 'Round'	9.65	18.71	28.36
15330	India	cv. 'Sativa'	16.90	13.35	30.25
15338	Puerto Rico	cv. 'Smooth Angled'	2.00	1.12	3.32
15472	Hawaii	cv. 'Poison'	10.60	22.09	32.69
15492	New Caledonia	cv. 'Thuma'	19.50	2.47	21.99
15500	Ivory Coast	Wild	1.70	.97	2.67
15501	do	Cultivated	1.87	3.74	5.61
15772	do	Very small tubers	.16	25.34	25.50
15773	Nigeria	cv. 'Olode'	3.00	.30	3.30
15774	do	Extremely small tubers	1.00	.93	1.93
15775	do	Purple flesh	2.50	1.83	4.33
15776	do	Small tubers	2.75	1.18	3.93
15777	do	Large lobes	1.49	1.93	3.42
15778	Sierra Leone	Wild	.05	.15	.20
15779	do	Cultivated	8.00	3.47	11.47

[1] Specimens in the living collection at the Federal Experiment Station, Mayaguez, P.R.

dant, well-shaped aerial tubers, some sweetness but no bitterness of flesh, and resistance to foliage diseases.

CULTURE

Environmental Requirements

Judging from the wide distribution of wild *D. bulbifera* varieties, the species grows in many kinds of soil. However, loams or loose clays with good drainage are preferred. A high level of organic material promotes vegetative and tuberous growth. The wild varieties require some protection from dry conditions, since the aerial tubers fall to the ground where they need moisture to germinate. An accumulation of leaves on the ground, as in the case of a wooded area, prevents the loss of soil moisture.

Most varieties of *D. bulbifera* require long rainy seasons. The bulbils of some varieties fall throughout the growing season and may germinate within a few weeks on the ground. In other varieties the bulbils are seasonally dormant. This behavior, accompanied by the dieback of foliage and its replacement 1 to 4 months later, is independent of rainfall conditions and may be an effect of photoperiod. The foliage of all varieties is annual; it eventually dies back and is replaced. Varieties differ in the length of the time between dieback of old and production of new foliage.

Land Preparation and Planting

D. bulbifera is seldom planted on a commercial scale. The techniques for cultivating it are not much different from those used for other species of yam. Usually the soil is heaped in hills or ridges to provide drainage and aeration, but this may not be necessary for this species. Special plowing is probably never done.

The bulbils, or aerial tubers, are used as seed. They have polarity (*1*) and thus germinate from certain eyes, where buds are formed at a very early stage. However, polarity is destroyed by cutting the bulbils. Large ones may be conveniently cut into several pieces. New buds can then be produced from the meristem of the cortex. Larger bulbil pieces produce healthier plants. After 2 or 3 days of drying and healing in a shady place, the cut pieces are ready for planting.

The bulbils pass through a definite period of dormancy unique for each variety. It is difficult to change this period significantly, for bulbils will not germinate until they are ready. The appropriate conditions (damp soil) can stimulate germination to some extent, but on the other hand, the bulbils will eventually germinate whether or not conditions are appropriate. In addition, although cool, dry storage is useful in inhibiting germination, the characteristics of the variety determine optimum planting time. The bulbils should be ready to germinate at the beginning of the rainy season, during the time of lengthening days.

The best plant spacing has not been investigated. In Puerto Rico good yields have been obtained by spacing the rows at 1.6 meters and the plants at 0.7 meter in the row.

Bulbils are planted 8 to 12 centimeters below the surface of the ground with a short hoe. Preemergence herbicides, such as atrazine at 3 kilograms per hectare, may prove useful in preliminary weed control. Later, contact herbicides can be used with caution.

Fertilization

Since the culture of *D. bulbifera* has not been studied systematically, experience with other yam species must serve as a guide. *D. bulbifera* grows best in a loamy soil, preferably high in organic material. The mineral requirements have not been investigated. Yams in general live from the nutritional reserves of their tubers for 4 to 6 weeks after germination. In the early months of the life cycle they benefit from good quantities of nitrogen, which promotes vegetative growth. Later, when tuber production begins, they require much potassium. Yams remove phosphorus from the soil efficiently; thus, low levels seldom limit growth.

In Trinidad, the following fertilization schedule has been recommended for *D. esculenta*: apply either 200 kilograms ammonium sulfate per hectare 3 months after planting or 400 kilograms com-

pound fertilizer high in potassium (11:11:13) per hectare 6 to 8 weeks after planting. Local trials with fertilizers are always desirable.

Staking

Yams are forest plants that climb by twining. Although some species produce satisfactory yields without staking, *D. bulbifera* plants require support. Primitive supports include bamboo stakes and branches. Sometimes the vines are allowed to climb trees or even banana plants, but such support puts the developing aerial tubers out of reach. Short supports (5 to 6 feet high), with lateral rods to facilitate coverage, permit easy harvest.

Pests and Diseases

Some varieties of *D. bulbifera* are somewhat susceptible to the leaf-spot diseases (especially *Cercospora*) seen in other species. Usually such diseases are seen only late in the season, when the foliage is beginning to die back normally. Another disease, stem rot, sometimes occurs, but it is not a serious condition. Premature drop of partially developed bulbils is frequent and may be associated with minor fungal infections during rainy weather. The underground tubers are sometimes attacked by nematodes and beetles, but they appear to be more resistant than tubers of other species.

Harvesting

Edible aerial tubers may be produced in as little as 3 months after planting. Tubers may be picked at any time, but immature tubers contain less starch and are less appetizing than mature tubers. Fully mature tubers fall to the ground, from which they can be removed for home use. On the other hand, mature tubers are easily dislodged from the stem with a slight twist. Since mature tubers are produced for several months, they may be harvested every week or two. When the vines die back, a few immature tubers are left.

The underground tubers are usually not harvested until the foliage dies back. They may then be harvested with handtools. Since they are usually compact and small, they are easy to harvest. The underground tubers can be left in the soil until needed.

Typical yields of 16 varieties are given in table 1. The yields of the better varieties have been tested various times. Improved cultural practices should double any of these yields.

Both aerial and underground tubers are resistant to fungal infections. Harvest wounds usually heal promptly, especially if cut tubers are exposed to dry air a few days. On the other hand, exposure to sunlight rapidly damages the tuber, and weight loss, internal breakdown, and rot result. Tubers for planting should be stored under cool, dry conditions.

CULINARY CHARACTERISTICS

The aerial tubers of some varieties are small and hard to peel,

but the better varieties are ideal and convenient for the kitchen. Moreover, the aerial tubers can be boiled or baked without peeling, although the peel may increase the bitterness of the adjacent flesh.

The flesh of the tuber is compact and hard. The large-tubered Asian varieties have softer flesh. When the tubers are boiled, the African varieties tend to remain firm, but the Asian varieties can easily be overcooked. The yellow color is usually darkened by cooking, and the resulting color may not be appetizing. The yellow color of the flesh makes the tubers unsuitable for fried chips and french fries, products in which the color must be appealing.

The flavor of each *D. bulbifera* variety is distinctive. The edible African varieties are almost always bitter, but the palate is easily accustomed to it, and somewhat bitter yams may be eaten with relish. Asian varieties have a softer, more succulent flesh, a smooth texture, and often a pronounced sweetness. Their flavor does not, however, have the richness of some varieties of *D. alata* and *D. rotundata*.

COMPOSITION

The composition of the aerial and underground tubers of an edible African variety were given by Wildeman (*13*) and are reported in table 2. The dry weight of the tuber ranges from about 12 to 35 percent of the whole-tuber weight. Immature tubers contain relatively less starch. The aerial and underground tubers differ very little in dry weight. How-

TABLE 2.—*Composition of tubers of an African variety of* D. bulbifera

[Percent of whole-tuber weight]

Substance	Aerial tubers	Underground tubers
Water	73.400	69.081
Starch	14.860	16.833
Cellulose	3.645	6.744
Sugars	.470	.451
Chlorophyll	.031	----
Fats	.230	.104
Brown resin (phenolics)	----	.304
Yellow resin (carotenoids)	1.660	.461
Albumins (protein)	.530	.890
Glutinous substances	2.304	.525
Tannins	----	.052
Soluble substances	----	1.442
Mucilage, pectins, dextrines	2.870	3.113

Source: Wildeman (*13*).

ever, African varieties are usually more compact and dense than Asian varieties. Of the dry weight, 80 to 95 percent is starch.

The bulk of the starch in *D. bulbifera* consists of fairly large particles, from 3 to 6.5 microns long. The particles are flat and triangular because of the buildup of size by successive layers at only one end. A large starch particle is not as easily digested as a small particle. In most varieties the amylose content of the starch is moderately low, 15 to 18 percent, but in one variety a high amylose content (28 percent) was found. *D. bulbifera* starch has a low viscosity and high gelatinization temperature. The characteristics of the starch suggest no special value or use for it.

The protein content is of considerable interest since yams contain sufficient protein to contribute significantly to dietary needs. Crude protein values are as high as 10 percent of the dry weight of the yam, but the quality of the protein is poor, especially with respect to the sulfur-bearing amino acids, methionine and cystine (table 3). The protein also lacks sufficient tyrosine and lysine. The tryptophan content is unknown. Varietal differences in amino acid content suggest that varieties with better amino acid content can be bred.

The yellow pigments of *D. bulbifera* unfortunately have no nutritional value. The carotenoids are entirely xanthophylls and their esters (*2*). These include, in de-

TABLE 3.—*Protein and amino acids in three cultivars of* D. bulbifera[1]

Cultivar	Protein	Alanine	Valine	Glycine	Isoleucine	Leucine	Proline	Threonine	Serine	Methionine
'Sharp Angled'	10.03	6.3	5.6	5.2	4.4	9.9	4.4	4.4	7.7	1.6
'Round'	8.88	7.3	5.1	4.2	3.7	7.8	3.7	4.5	8.0	1.4
'Sativa'	10.17	6.2	6.1	5.1	4.4	9.7	4.7	4.9	7.4	1.6

Cultivar	Hydroxyproline	Phenylalanine	Aspartic acid	Glutamic acid	Tyrosine	Lysine	Histidine	Arginine	Cystine
'Sharp Angled'	0.1	6.0	12.9	12.9	3.6	4.3	3.0	7.5	0.7
'Round'	.2	4.9	10.7	14.5	2.7	3.0	2.7	4.1	.2
'Sativa'	.1	6.5	14.4	14.6	3.6	3.8	2.8	5.4	.5

[1] Values of amino acids are milligrams per 100 grams of yam, dry weight. Protein content is given as percent of dry-tuber weight.

creasing order of importance, lutein, neoxanthin, violaxanthin, auroxanthin, and cryptoxanthin. Such pigments are normally found in leaves and stems, and their occurrence in tubers is suggestive of the origin of these tissues from stem tissue. Aerial tubers also contain chlorophyll. The occurrence of anthocyanins in tubers of *D. bulbifera* is common.

Poisonous or Obnoxious Contents

That the tubers and bulbils of some varieties of *D. bulbifera* are poisonous is well known and often put to use (*5*). On the island of Java the aerial tubers are used to make fish poison. In Africa poisonous varieties are planted among the nonpoisonous in order to confound and discourage thieves. Presumably the farmer himself distinguishes the poisonous yams by remembering where he planted them or by minor morphological differences. Chevalier (*2*) distinguished his varietas *contralatrones* on the basis of its poisonous content only. Karnick (*5*) reported cases of death from ingestion of the tubers, and Wildeman (*13*) reported the death of 38 soldiers who had eaten poisonous varieties. Poisonous yams have been used in Africa to control criminals (*3*). Perhaps from their poisonous qualities, the belief in the power of the plants to impede intruders, whether human or animal, is commonplace in Africa.

One of the poisonous substances of *D. bulbifera* is apparently dioscorine, an alkaloid found in many poisonous yams and sometimes used as a heart stimulant. On the other hand, a saponin has sometimes been reported. Up to 4.5 percent of the saponin dioscine has been reported (*4*), but this content seems excessive, and other accounts estimate the steroidal sapogenin as nil.

Tubers of the poisonous and nonpalatable varieties of *D. bulbifera* are often used as food after special processing (*5*). Treatments include prolonged or repeated boiling, often with wood ashes, and steeping the tuber slices in running water. Another technique is to pound the tubers with lime or sand and then roast them slowly. Treatments may include all of these steps. Perhaps in part because of the complexity of the operation, the tubers are often used only as an emergency food.

Tubers of *D. bulbifera* are often bitter. In a search for sapogenins, Kawasaki et al. (*6*) discovered a new series of bitter substances, furanoid diterpenes, but Telek et al. (*12*) showed that these substances also occur in the sweet varieties. Other related substances are not bitter. Probably all *D. bulbifera* varieties contain small amounts of bitter substances in concentrations often below the level of detection by taste only. The bitter substances are most soluble in methanol, but they can be removed to some extent by prolonged

boiling or soaking in water. The nutritional significance of the bitter substances is not known, but there is no reason to believe they are poisonous.

Folk Medicine

The aerial and underground tubers have been used many ways in folk medicine (*5*). In India the bulbils have been used externally for sores and internally for hemorrhoids. Among the Santals of central India a paste from the tuber is used for swellings and as a cure for snakebite. In Burma, tubers are used as galactagogue. In Jamaica the tuber is used for the treatment of scorpion stings and ulcers. In Africa extracts are used in toddy to stimulate excessive drinking.

POTENTIAL USES

The potential of *D. bulbifera* is undoubtedly in the home garden, where its health and vigor commend it for growth under uncontrolled conditions. The fact that an edible crop is borne over 4 to 5 months makes this yam particularly desirable. No other edible species is equal in this respect. The spherical or ellipsoid shapes of the better varieties make preparation in the kitchen simple. The well-textured flesh of the African varieties is easy to appreciate, but the varieties are usually bitter. In addition, they are irregular in shape. The Asian varieties have a softer flesh that needs less cooking.

The best Asian varieties of *D. bulbifera* merit collection, trial, and widespread distribution. Because of their potentially high yields, they should be magnificent producers of edible flesh and starch. Their commercial potential has not been well tested. Processing techniques comparable to those used for potatoes need to be tested and developed for this species.

The necessary research does not seem to be in progress anywhere. Thus their potential is still undiscovered.

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